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ABSTRACT

The purpose of this study was to examine the effects of different levels of visual elaborations and practice on application learning of adults in a computer-based science lesson. A total of 141 university students participated in an introductory lesson covering Newtonian mechanics. Three levels of visual elaboration (static graphic, animated graphic, no graphic) were crossed with three levels of practice (behavioral, cognitive, no graphic). Behavioral practice consisted of traditional questioning after each of four lesson parts. Cognitive practice consisted of a structured simulation involving the control of an animated "starship." No effects were found for visual elaboration. The addition of static and animated visuals to the text had no effect on learning. An effect was found for practice such that both types of practice were effective (as compared to a control), but no differences between them were detected. Main effects were found for visual elaboration and practice based on response latency data from the posttest. A moderately significant interaction between visual elaboration and practice indicated several trends for future research. Two tables display the results of data analyses and one figure depicts the interaction between visual elaboration and practice. (32 references) (Author/CGD)

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Title:

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The Effects of Computer Animated Lesson Presentations and Cognitive Practice on Adult Learning in Physical Science

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The Effects of Computer Animated Lesson Presentations and Cognitive Practice on Adult Learning in Physical Science

Abstract

The purpose of this study was to examine the effects of different levels of visual elaborations and practice on application learning of adults in a computer-based science lesson. A total of 141 university students participated in an introductory lesson covering Newtonian mechanics. Three levels of Visual Elaboration (Static Graphic, Animated Graphic, No Graphic) were crossed with three levels of Practice (Behavioral, Cognitive, No Graphic). Behavioral Practice consisted of traditional questioning after each of four lesson parts. Cognitive Practice consisted of a structured simulation involving the control of an animated "starship". No effects were found for Visual Elaboration. The addition of static and animated visuals to the text had no effect on learning. An effect was found for Practice such that both types of practice were effective (as compared to a control), but no differences between them were detected. Main effects were found for Visual Elaboration and Practice based on response latency data from the posttest. A moderately significant interaction between Visual Elaboration and Practice indicated several trends for future research.

Introduction

Since the introduction of microcomputers in educational settings, a great variety of instructional applications have been presented. Most recent designs of computer-based instruction (CBI) have attempted to create instructional environments which integrate wide ranges of learning outcomes encompassing recent advances in learning theory and instructional design (see for example Jonassen, 1988; Wager & Gagné, 1988; Ross & Morrison, 1988; Tennyson & Christensen, 1988). Despite these advances, we know surprisingly little about some of the computer's most basic presentation attributes. Animation is one such attribute which has little empirical support although it is widely incorporated as a CBI presentation strategy (Rieber, 1989a).

General theoretical support for visual presentations, of which animation is a subset, comes from several information-processing learning theories (Gagné, 1985). Imagery, the visualization of knowledge in continuous dimensions, has been shown to be particularly useful in working memory because of the compact manipulation of spatial information (E. Gagné, 1985). Whether imagery is used as extensively in long term memory is not as conclusive. One theory supporting visualization's role in long term memory is the dual-coding hypothesis (Paivio, 1979, 1983) which suggests that highly imageable, concrete information is stored both verbally and visually. Retention can be enhanced by external pictures if they promote the activation of dual-coding. When information is dual-coded, the probability of retrieval is increased since if one memory trace is lost, another is still available (Kobayashi, 1986).

Of the few empirical studies that have been reported investigating the effects of animation as a presentation variable with adults few have indicated positive results (see, for example, Caraballo, 1985; King, 1975; Moore, Nawrocki, & Simutis, 1979; Reed, 1985; and Rigney & Lutz, 1975). However, factors such as the limited number of studies, evidence of procedural flaws, and other confounding in some of these studies, make generalization difficult. Recently, Rieber (1989b) reported positive results when animated visuals were used to present science concepts and rules to young children, but only under certain conditions (eg. animation congruent to learning task, careful cueing to attend to animation, and the use of optimally difficult material). Related research in mental imagery has indicated maturation effects. Older students consistently rely less on external images than younger students (Pressley, 1977). Whether the previous lack of animation effects with adults was due to maturation effects or to inappropriate or insufficient research is open to question and was the basis for this study.

Besides visualization, animation also offers the attributes of motion and trajectory to instructional presentations (Klein, 1987). Animated visuals should be expected to promote learning

when motion and trajectory attributes are congruent to the learning task and students are unable to mentally construct such attributes on their own adequately. Many objectives in physics instruction present examples of this. Problems in teaching physics concepts have also been compounded by many reports of student misconceptions of the physical world (diSessa, 1982).

Practice has long been accepted as an effective learning strategy. Many practice strategies are operationally defined as asking questions before, during, and/or after instruction (Hamaker, 1986). This type of practice tends to be somewhat behavioral in nature — enhancing factual and conceptual learning through repetition. While this type of practice is effective (see for example Hannafin, Phillips, Rieber & Garhart, 1987; and Hannafin, Phillips, & Tripp, 1986), especially for lower-level learning outcomes, it tends to become monotonous or boring for the student and relies heavily on extrinsic motivation. In CBI, this type of practice has been commonly applied to much tutorial and drill and practice software.

Practice does not have to be limited to just the encoding of facts, but can also aid higher-level cognitive processing (Salisbury, 1988; Salisbury, Richards, & Klein, 1985). This type of practice involves presenting the learner with problems or conflicts that need resolved through higher-level processing such as informal hypothesis-testing. This is a more cognitive approach to practice design in that it provides intrinsic motivation (Malone, 1981) for students to become involved in deeper levels of mental processing. CBI affords many innovative and relatively unique practice scenarios to be designed.

The purpose of this study was to study the effects of animated instruction and practice on adult learning in science. This study was a replication of the study by Rieber (1989b) which found effects of animated visuals on children's learning. In this experiment the question of whether animated visuals would also influence adult learning or if adults would be able to sufficiently construct such images internally thus making the addition of animated visuals unnecessary was studied. Additionally, the role of varied practive activities and their relationship to presentation variables were also studied.

Methods

Subjects

The subjects consisted of 141 upperclass undergraduate students (juniors and seniors). All of the students were education majors currently enrolled in an introductory computer education course. Participation was voluntary, though extra credit in the enrolled course was provided as an incentive to participate. A total of 122 females and 19 males participated.

CBI Lesson Content

The CBI lesson described and explained Isaac Newton's Laws of Motion. The lesson was divided into four parts. The first part introduced the student to fundamental background vocabulary and concepts, such as mass, weight, inertia, force, velocity, and acceleration. This part also formally presented Newton's first law of motion. The second part introduced Newton's second law of motion and then described applications of Newton's first and second laws given equal forces in opposite directions in one-dimensional space. The third part extended the application of Newton's first and second laws to include the effects of unequal forces in one-dimensional space. The fourth part introduced and explained Newton's third law and applications in two-dimensional space. All instruction was presented at an introductory level intended for novices. The lesson was designed to exclude as much formal mathematics as possible and instead concentrated on concept formation and application. Approximately 60 minutes was required to complete the lesson.

Lesson Versions

Three levels of Visual Elaboration (Static Graphic, Animated Graphic, No Graphic) were crossed with three levels of Practice (Behavioral, Cognitive, None). The respective practice activity was provided immediately after each of the four lesson parts.

Behavioral Practice. This consisted of five multiple-choice questions presented after each of the four lesson parts for a total of 20 practice questions. The questions covered the application of

information contained in each respective lesson part. Informative feedback was provided to the students in the form of knowledge of correct results. This condition is described as behavioral due to the reinforcing nature of the practice activity.

Cognitive Practice. This activity consisted of a structured simulation. Students were given increasing levels of control over a simulated, free-floating object. This object was called a "starship" and was represented by a triangular symbol on the computer screen. This practice activity is an application of the "dynaturtle microworld" developed by diSessa (1982) and others (White, 1984). This practice activity is an example of a "learning-by-doing" application of animation (Brown, 1983), also described as an interactive dynamic (Rieber, 1989a). For example, students practiced increasing and decreasing the starship's speed after lesson part 3 and practiced controlling the starship when forces are applied to it orthogonally (in 90 degree increments) in part 4.

No Practice. This level acted as a control. No practice activity was given to these students, instead, they progressed sequentially through the four lesson parts.

Each of the three levels of Practice was crossed with three levels of Visual Elaboration (Static Graphic, Animated Graphic, No Graphic). Visual elaborations were added to an all-text lesson script. These visual elaborations were added at regular intervals at locations in the text where particular rules and applications of one or more rules were being explained.

Static Graphic. The textual presentation of the science instruction was supplemented by static graphics. These graphics provided static illustrations of the science content. Forces were represented graphically by a foot giving an object (usually a ball) a kick. Motion and trajectory attributes were represented by arrows and dotted path lines.

Animated Graphic. In this condition, each static graphic was replaced with an animated graphic. The foot and ball graphics were also used to show an object being acted upon by forces, however, the ball was additionally animated to demonstrate the consequences (in terms of speed and trajectory) on its movement. For example, a stationary ball was shown being kicked two times to the right. The ball was animated across the screen to the right and then stopped by two kicks to the left. This demonstrated the principle that an equal force in the opposite direction is needed to stop the object.

No Graphic. This level acted as a control. No visual support was added to the textual presentation in this condition. The textual material was verbatim to the other two Visual Elaboration conditions.

Dependent Measures

Lesson Posttest. The posttest originally consisted of 32 questions measuring application learning corresponding roughly to rule-learning as defined by Gagné (1985). However, 13 questions were subsequently removed before the final analysis due to their lack of discriminiation ability as indicated by follow-up item analyses. The remaining 19 questions were used in the final analysis. Multiple-choice questions (1 answer and 4 distractors) were used as the testing format. The posttest measured student performance on the following six lesson objectives:

1) apply the rule that, without any outside forces, an object in motion will remain in motion and an object at rest will remain at rest (Newton's first law);
2) apply the rule that, in one-dimensional space, when an object at rest is put into motion by a force, an equal force applied in the opposite direction is needed to stop the object;
3) apply the rule that, in one-dimensional space, when an object is acted on by unequal forces, the final speed and trajectory of the object is the result of the sum of the forces acting on the object from both sides;
4) apply the rule that, in two-dimensional space, forces occurring at right angles to each other act independently on the object (orthogonality);
5) apply Newton's second law, summarized by the equation force=mass times acceleration (F=ma); and
6) apply the principle of the relationship between acceleration and velocity.

The format of these questions was approximately half all-verbal and half verbal/visual and about half of the verbal/visual questions involved animation. No feedback was provided after each question, but students were given their total number of correct and wrong responses at the conclusion of the posttest. KR-20 reliability of the original 32 questions was .71.

Response Latency. The time required by students to answer each posttest question was measured to the nearest second. Response latency was measured as the time required by students to answer each of the posttest questions once prompted to do so. The prompt was the final text displayed on the screen for each question.

Notetaking. Students were provided paper for any notes they wished to take during the lesson presentation. These notes were analyzed in terms of content, style, quality, and quantity in relation to the lesson presentation in which they participated.

Post-lesson Survey. Upon completion of the lesson, students completed a post-lesson survey. Students were asked to respond to open-ended questions which addressed issues such as the difficulty of the lesson, how the lesson might have hindered their learning of the material, and how the lesson might have helped their learning of the material. The students comments were summarized with respect to the content and specific examples cited.

Procedures

All instruction and testing was administered by computer. Subjects were randomly assigned to one of the treatment groups as they reported to the lab. Before beginning the lesson, all students were given a group orientation to the lesson. All subjects were supplied with paper and asked that it be used for any notetaking. All notes were collected by the proctor at the end of the experiment. Once instructed to begin, students completed the computer lesson individually. The posttest was automatically administered to each student upon completion of the four lesson parts. Immediately upon completion, students were informed of their posttest score. Students were then asked to answer the post-lesson survey. Approximately one hour was needed to complete the lesson.

Design and Data Analysis

A 3 X 3 X (6) factorial design was used in this study. Two between-subjects factors (Visual Elaboration, Practice) were crossed with one within-subjects factor (Learning Objective). The between-subjects factors consisted of three levels of Visual Elaboration (Static Graphic, Animated Graphic, No Graphic) and three levels of Practice (Behavioral, Cognitive, No Practice). The within-subjects factor consisted of the six learning objectives which also served as a dependent measure. Statistical procedures included mixed-effects analysis of variance (ANOVA) and Tukey's studentized range test for follow-up multiple-comparisons on means. In addition, a separate analysis was conducted on the response latency data from the posttest.

Besides the quantitative measures, qualitative data in the form of student notetaking and post-lesson surveys were also also analyzed.

Results

Posttest

Percent means and standard deviations of student posttest scores are contained in Table 1. The ANOVA summary table is contained in Table 2. No main effects were found for Visual Elaboration, $F(2,660)=1.62$, $p=.199$. Students performed similarly on the posttest regardless of presentation strategy.

A significant main effect was found for Practice, $F(2,660)=12.19$, $p=.0001$. Follow-up analyses showed that students in the Cognitive Practice group (mean=76.4%) and Behavioral Practice group (mean=81.1%) both outperformed students in the no practice control group (mean=69.2%). No significant difference was indicated between the Cognitive and Behavioral Practice groups.

Insert Table 1 About Here

Insert Table 2 About Here

A significant main effect was found for Learning Objective, $F(5,660)=3.37$, $p=.005$. As expected, learning was not uniform across all of the lesson objectives. The follow-up analysis indicated a significant difference between posttest scores on objectives 2 (mean=80.1%) and 3 (mean=81.4%) and objective 6 (mean=70.1%). It was expected that students would find the final objective involving acceleration and velocity problems the most difficult.

A moderately significant difference was detected between Visual Elaboration and Practice, $F(4,660)=2.19$, $p=.068$. The nature of this interaction is shown in Figure 1. This interaction suggested two trends in the data. First, the Static Visual and No Visual groups appeared to be influenced more by practice than the animated visual group. That is, when practice was not provided, the Animated Visual group outperformed the other two visual groups. Second, it appeared that cognitive practice caused interference when the lesson was presented using animated visuals.

Insert Figure 1 About Here

Response Latency

A main effect was found for Visual Elaboration, $F(2,660)=4.89$, $p=.008$. Students in the Animated Graphic condition (mean=18 seconds) took significantly less time to answer posttest questions than either students in the Static Graphic (mean=20 seconds) or No Graphic (mean=20 seconds) conditions.

A main effect was found for Practice, $F(2,660)=22.57$, $p=.0001$. All three practice conditions were significantly different from one another. Students in the Cognitive Practice condition (mean=17 seconds) took significantly less time to answer the posttest questions than those in the Behavioral Practice condition (mean=19 seconds). Students in these two conditions took significantly less time to answer posttest questions than students in the No Practice (mean=22 seconds) condition.

A main effect was also found for Lesson Objective, $F(2,660)=50.51$, $p=.0001$. Three distinct ranges of response latency among the lesson objectives grouped the objectives as follows: the first group comprised objective 5 (mean=26 seconds); the second group comprised objectives 1 (mean=22 seconds), 4 (mean=21 seconds), and 6 (mean=20 seconds); and the third group comprised objectives 2 (mean=15 seconds) and 3 (mean=12 seconds). All three groups were significantly different from each other.

Note Taking

During the lesson students were permitted, although not prompted, to take any notes they wished. Of the 141 students, 82 students (evenly distributed across all presentation formats) filled most of an entire page with notes, and 26 students took no notes as all. The types of notes were consistently the same: lists of factual information, formulas, and statements of the laws of motion. Virtually no students added their own comments or interpretations of the information. Twenty-six students included diagrams reflecting solutions to some of the questions on the posttest.

Post-Lesson Survey

In response to consider which attributes of the lesson aided their learning, all groups mentioned that review, repetition, self pacing, and examples provided the greatest amount of help. In general, students recognized general lesson design features as aids to learning. Students in the Static Graphic condition specifically mentioned that the graphic displays were helpful, while students in the Animated Graphic condition mentioned that the animation and motion were helpful. Students in the No Graphic condition cited the lesson examples as being helpful.

With respect to practice, students in the Behavioral Practice condition specified the practice questions and examples as being helpful, while students in the Cognitive Practice condition referred to the participation, involvement, and "fun practice" as being helpful. Students in the No Practice did not make any additional comments.

When asked what might have hindered their learning, all groups mentioned the amount of information presented, expressing concerns that it was "too much". A second concern was not being able to return to a previous screen to review the material. It is interesting to note that students in the Animated Graphic condition mentioned that the "rolling balls" took too long, while students in the Static Graphic condition specifically mentioned that examples of a moving ball and kicks were needed. Students in the No Graphic condition specifically mentioned that pictures and graphics were needed and would have been helpful.

The Behavioral Practice group did not mention any specific concerns, but students in the Cognitive Practice were concerned that the program was lengthy, specifically in the practice activities. Many students in the No Practice condition expressed the concern that they were not completely prepared for the posttest.

General Discussion

The purpose of this study was to investigate whether previously indicated effects of animation used as part of presentation and practice strategies on children's learning of certain science material (Rieber, 1989b) would be replicated using adults. The science material taught Newton's three laws of motion and was chosen for its conceptual density and its obvious congruency with animated instruction. Previous research using this science material with young children has indicated animation and practice effects, but only under certain conditions. For example, in the Rieber (1989b) study young children benefited from animated presentation strategies only when the learning task was optimally difficult and when they were carefully prompted to attend to the animation. Other animation research with adult subjects has largely reported no significant differences. However, general imagery research points to maturation effects (Pressley, 1977) where an individual's dependence on external imaging prompts appears to fade with age. This study was an attempt to validate empirically the relationship of the visual effect of animation and maturation using material found to produce an effect with young children but revised (in terms of reading level and concept density) to reflect the adult sample.

No main effects for Visual Elaboration were found in this study. Adult subjects in this study were not influenced by the type of presentation strategy used. The verbal material was presented to subjects using highly imageable explanations and examples. Although subjects found the lesson material relatively difficult (overall mean = 75.6%) such that ceiling effects can be excluded, the addition of static or animated visuals to provide more concrete elaborations of the verbal material did not contribute to learning. This lack of effects for animated presentation strategies is consistent with previous research with adult learners.

It is contended that successfully performing the task requirements of this lesson required subjects to perform three imaging functions: 1) adequate visualization of the physical science material; 2) adequate and accurate imaging of differences in the motion of objects (i.e. moving, not moving, changes in speed); and 3) adequate and accurate imaging of the trajectory of objects (i.e. direction of the path of the moving object). The verbal presentation of the lesson material was designed to act as a stand-alone presentation vehicle. It sufficiently provided all information by way of highly imageable explanations and examples as well as prompts to students to image. It was believed that this design would support individuals capable of internally imaging these three functions. Students given an all-verbal presentation would be required to form internal mental images. Static and animated visual elaborations of the verbal information were then added to successively provide more concrete, external imaging devices. In this study, subjects provided with these external imaging devices performed as well as subjects who were given an all-verbal presentation.

The response latency data indicates that although animation did not affect learning, it helped to decrease the time necesssary to retrieve information from long-term memory and then subsequently reconstruct it in short-term memory. This retrieval process required students to reconstruct mental images. The animated visual presentation significantly aided the students in this mental visualization effort as compared to students in the static or no visual conditions. Comments on the survey from students in the visual groups that visuals helped them as well as comments from students in the No Visual group that visuals would have helped supports this contention.

Practice has a long history of support as an instructional activity. Not only is its use intuitively obvious, but is well supported in instructional design theory (Gagné, 1985). Operational definitions of instructional practice often turn out to be forms of questioning, largely a result of the pioneering work of Rothkopf (1966). However, advances in cognitive psychology coupled with instructional opportunities available with computer technology present many interesting practice activities not yet sufficiently tested or validated. In this study, two practice conditions were tested. The Behavioral Practice group received a traditional questioning activity, whereas the Cognitive Practice group participated in a structured simulation involving the control of an animated "starship" in a frictionless/gravity-free environment. Both practice groups significantly outperformed the No Practice control group. However, no significant differences were found between the practice groups. One conclusion of no great surprise is that interactivity of any sort aids learning more than no interactivity. However, it was expected that the cognitive activity would promote higher-level learning more than the behaviorally-based questioning approach. Several researchers have discussed the benefit of behavioral designs in promoting lower-level learning and cognitive designs for higher-level learning (Clark, 1984). In this study, both practice types were equally effective. This could have been caused by the fact that the questions sufficiently required students to process the information at deeper levels of processing or because students were not given enough time and experience with the cognitive activities to produce a differentiated effect. At the very least, the structured simulation activity has been partially validated as an innovative instructional activity shown to be as effective as more conventional practice activities.

The response latency data supports the contention that both practice conditions facilitated students' organization of the material and their understanding of the relationship among the many concepts and rules. Even though no differences in learning was indicated between the two practice groups, the Cognitive Practice group took even significantly less time to answer posttest questions than the Behavioral Practice group. This provides partial evidence of the fact that this group may have processed the information at a deeper level (as defined by Craik & Lockhart, 1972) than students in the Behavioral Practice group. Comments from students in the No Practice group accurately reflected their lack of preparedness for the posttest.

The moderately significant interaction between Visual Elaboration and Practice was interesting. Two trends were indicated. The first trend seemed to indicate that the Static Visual and No Visual groups were influenced more by practice (Behavioral and Cognitive) than the Animated Visual group. In other words, students appeared to benefit most from the practice activities when the lesson presentation support was minimal. The second trend seemed to indicate that some interference occurred between the animated lesson presentations and the cognitive practice activities. Reasons for

this interference can only be speculated. Research indicates that children and adults have many misconceptions of physical science principles (Champagne, Klopfer, & Gunstone, 1982; diSessa, 1982). These misconceptions are based in part on each individual's personal theories of the physical world developed through daily experiences where the forces of gravity and friction are so prevalent. It is possible that the Cognitive Practice condition paired with precise animated presentations of the physical principles forced many students to confront several of these misconceptions. Since this experiment lasted only for one lesson, there was insufficient time and experience with the material to help students to remove or reconcile the inconsistencies between scientific reality and their misconceived "reality", hence, the students' learning of the material was interfered.

In summary, the results of this study indicate that the inclusion of animated instruction may be unnecessary given verbal presentations which are carefully designed to provide adult students with highly imageable explanations and examples and which effectively prompt these students to form such internal images. Although some research has indicated that there are conditions under which animated visuals can be effective for presentation purposes, such as occasionally with young children, this effect has yet to be replicated with adults. However, the response latency data indicated that the animated visuals facilitated initial encoding and subsequent retrieval, thus aiding learning. Successful applications of animated visuals with adult populations have been reported when the animation is used as an interactive dynamic (Collins, Adams, & Pew, 1978; Rieber, 1989b; White, 1984). In this study, such an interactive dynamic was used as a cognitive practice activity, and was shown to be an effective influencer of higher-level learning, although no more so than traditional approaches. It is important to note that it is very difficult to distinguish animation's role when used as part of an interactive dynamic, as the experience is largely context specific (Rieber, 1989a). More research is needed to clarify other applications of the conditions under which interactive dynamics are and are not effective. Additionally, the suggested interaction between animated presentations and interactive dynamics which indicated possible interference to learning needs more clarification.

A conclusion of this research is that CBI designers should be encouraged to continue to design creative and innovative interactive dynamics as it appears that the time necessary to design such animated visuals is worthwhile. In contrast, animated <u>presentations</u> can probably be effectively substituted with well-designed verbal presentations, with and without static graphics, which effectively prompt older students (adults) to form internal images. More research is needed in other content areas and instructional situations in order to determine the boundaries of these effects.

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Table 1

Mean Percent Scores and Standard Deviations for the Posttest

Visual Elaboration		Practice		
		Behavioral	Cognitive	None
Static Graphic	Mean	80.5	77.3	64.0
	SD	(28.3)	(32.0)	(36.6)
	n	16	16	16
Animated Graphic	Mean	81.6	70.2	72.3
	SD	(26.9)	(33.7)	(35.5)
	n	15	15	15
No Graphic	Mean	81.2	81.4	71.5
	SD	(30.2)	(28.7)	(33.1)
	n	16	16	16

Table 2

ANOVA Summary Table

Source	*DF*	*MS*	*F*	Probability
(V)isual Elaboration	2	1337.45	1.62	0.199
(P)ractice	2	10073.25	12.19	0.0001*
(V)(P)	4	1813.02	2.19	0.068
Error	660	826.39		
(L)esson Objective	5	2782.82	3.37	0.005*
(V)(L)	10	1051.05	1.27	0.243
(P)(L)	10	771.01	0.93	0.502
(V)(P)(L)	20	764.02	0.92	0.556
Error	660	826.39		

*$p<.01$

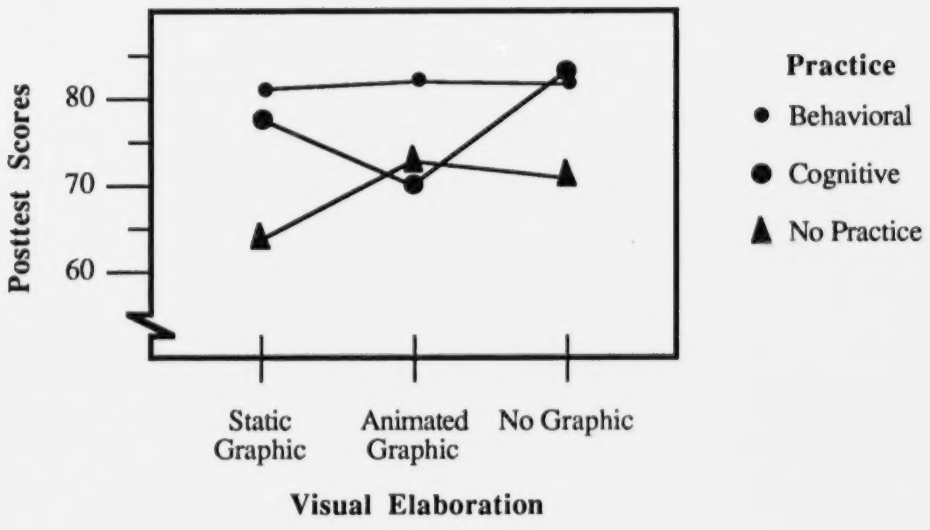

Figure 1. Interaction between Visual Elaboration and Practice.